Carabee
W. S. Ballard + E. M. Johnson.

Kentucky
Agricultural Experiment Station

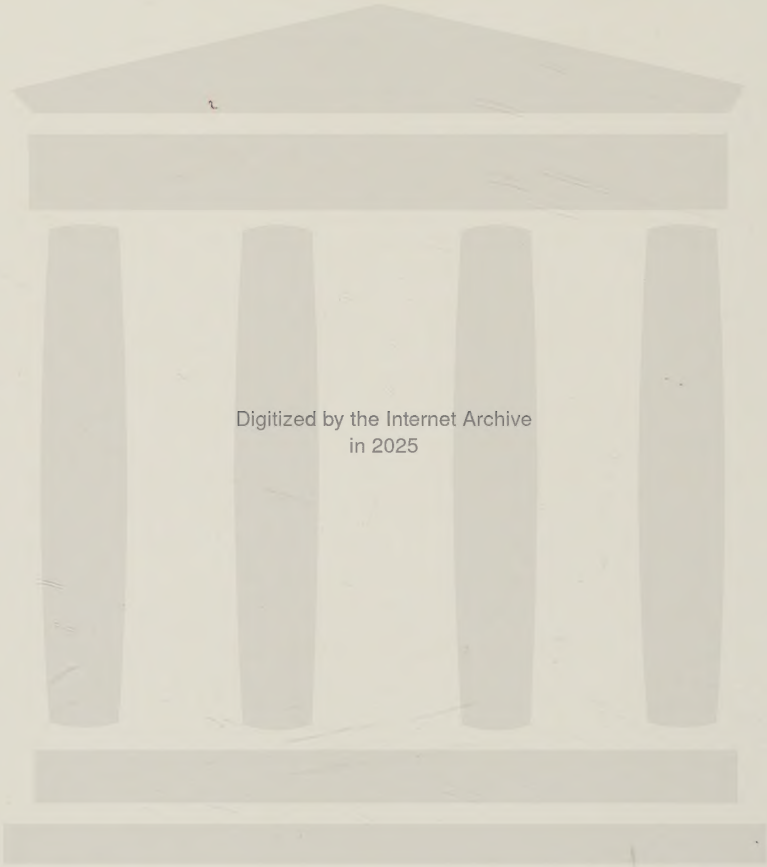
University of Kentucky

TOBACCO MOSAIC
SOURCES OF INFECTION AND CONTROL

BULLETIN NO. 376

Lexington, Ky.
December, 1937

(221)


Digitized by the Internet Archive
in 2025

https://archive.org/details/bulletin-kentucky-agricultural-experiment-station-uky_1937-12_376

Bulletin No. 376

Tobacco Mosaic
Sources of Infection and Control

W. D. VALLEAU and E. M. JOHNSON

Tobacco mosaic control depends upon determining the sources of initial infection in the plant bed and field and eliminating them, and eliminating, or avoiding touching infected plants in the field, to avoid spread. Until comparatively recently the causes of the occurrence of mosaic in plant beds and fields were not known but now that much evidence on the source of infection has been accumulated, it seems desirable to evaluate it and try to arrive at some conclusion as to the most common sources so that the best methods of control may be developed. As long as there is disagreement as to the chief sources of plant-bed and field infection, it will be virtually impossible to test uniformly the value of recommended practices (18, 20, 23) in all the tobacco-growing areas of the country. It is proposed in this Bulletin to analyze the material which has been published on sources of mosaic infection and add experimental and observational evidence on sources of infection and on control.

FOUR SOURCES OF INFECTION

Because it retains infectivity after drying, tobacco mosaic virus is in a class alone among the viruses which affect annual plants, as far as sources of infection and control measures are concerned. Four possible sources of tobacco mosaic virus must be given consideration in control of mosaic: 1, the contaminated hands of workers, and tools and equipment used in caring for the crop; 2, the living infected plant and dying or dead plant parts; 3, insects temporarily made viruliferous, and 4, contaminated soil.

PERSONALLY USED TOBACCO A SOURCE OF MOSAIC

Mayer (17) in 1886 probably presented the first evidence, inadvertently, that man himself is chiefly responsible for infection in

the field. He stated in a footnote that "Many held the opinion that the manner of setting is of great importance. This went so far that, in Amerongen, any worker who was reputed not to be good at transplanting and therefore had much mosaic tobacco to answer for, was nicknamed Mosaic Johnny (Jan Bont). However, opinions as to what constituted faulty transplanting were diverse ('bunt')."[1]

Workmen Introduce Infection. In 1922 the senior writer began to keep records of distribution of tobacco mosaic in the plantings on the Kentucky Experiment Station farm. No information was available on the source of plant-bed infection other than that of Clinton (7) who showed that where tobacco decoctions and other tobacco material had been added to the bed, mosaic followed. On the Kentucky Station farm infected *Solanum carolinense* and *Physalis sp.* were common. Consequently a permanent plant-bed site was established and the weed hosts were eliminated from it. In 1924 the beds appeared to be free from mosaic at first pulling but in certain rows in the field set with plants from them about 30 percent showed mosaic when growth began. Other groups of rows were nearly or quite free from infection. In 1925, after a similar experience, it was concluded that elimination of *Solanum carolinense* and *Physalis* from tightly boxed and covered beds which were not weeded had no effect whatever in reducing mosaic in the field. Tests showed that in all probability infection arose from chewing tobacco used by workmen (4).

Barn-cured Tobacco. The 1924 planting (20) was on a plot which had had tobacco heavily infected with mosaic the previous year, but the distribution of mosaic in the field clearly indicated that infection occurred during pulling or setting and could not have come from the soil. In 1925 the plot used had not grown a crop of tobacco for 4 years. The plant bed was free from mosaic at pulling time. Both men who pulled plants were in the habit of chewing barn-cured tobacco but one used no tobacco until near the end of pulling when he chewed 5-year-old dark-fired tobacco subsequently found to be contaminated, while the other puller chewed manufactured plug while pulling. Neither man washed his hands before commencing pulling and consequently their hands must

1 Translation by the authors.

have been contaminated with virus. Mosaic occurred thruout the field in about the proportion shown in rows 115 to 124, (table 1). Higher infection in the last 8 rows was evidently caused by the puller who began chewing barn-cured tobacco toward the end of pulling. The lower infection in the remainder of the field might have originated from the commercial plug, but more probably came from the hands of the workers which were already contaminated from barn-cured tobacco before pulling commenced. It could not have arisen from the soil or from the plant bed. The distribution given in table 1 is typical of that caused by workmen who chew or smoke contaminated tobacco while pulling plants.

Table 1. Distribution of mosaic typical of that originating from contaminated hands of workers at pulling time. Record made about 30 days after setting, 1925.

Row number	Mosaic plants	Healthy plants
115	3	92
116	0	98
117	1	96
118	1	102
119	1	94
120	0	99
121	7	93
122	0	96
123	0	97
124	1	101
125	5	90
126	4	98
127	16	75
128	17	85
129	8	89
130	17	83
131	5	95
132	7	83

In 1926 the farm hands were given sterile manufactured and sterile barn-cured tobacco to chew while pulling and setting. Forty-four hundredths of one percent mosaic developed about three weeks after setting, in plantings including about 60,000 plants. This was only 1/18 the amount of infection which occurred following setting in the three years, 1922-1924, when no precautions were taken to control mosaic. In 1927, with the same precautions, 35 mosaic plants were found in a total of about 70,000 plants set on the farm. It appeared certain from these results and experiments in which the hands were dipped in inoculum made of dried mosaic

tobacco and water, and tests in which pullers chewed contaminated tobacco while pulling and others pulled with clean hands, that a plant bed might be entirely free from mosaic at pulling time, but a heavily-infected crop might be set from it in land which had not grown tobacco for years, if the men who pulled plants chewed contaminated tobacco while pulling (table 2); and that contaminated hands of weeders offered the correct explanation for plant-bed infection where mosaic was found in the bed before pulling time. The results of these studies were published in 1927 in Kentucky Agricultural Experiment Station Bulletin 280 (20).

Table 2. Mosaic infection from the hands of workers. Plants pulled while hands of puller were contaminated by handling or chewing barn-cured tobacco compared with plants pulled with clean hands. In each set of tests plants were pulled from the same plant bed.

	Treatment	Mosaic Plants	Healthy Plants	Percent Mosaic
Lexington				
1926	Hands dipped in decoction of barn-cured tobacco	99	41	70.7
	Clean hands	0	138	0.0
1927	Chewed barn-cured tobacco and occasionally spit on hands	62	78	44.3
	Clean hands	0	80	0.0
1927	Chewed barn-cured tobacco, wiped mouth occasionally	39	839	4.4
	Clean hands	1	836	0.1
	Chewed barn-cured tobacco	19	341	5.3
1928	Contaminated soil. Puller chewed 2-year-old barn-cured tobacco. Plants in even numbered rows 2-34	33	889	3.6
	Odd rows 1-35, clean hands	0	1,015	0.0
1928	Puller who chewed barn-cured tobacco, washed hands in water only and then used sterile plug	32	553	5.5
	Same puller, virus largely worn off hands	17	54,325	0.03
Princeton				
1926	Chewed barn-cured tobacco, wiped mouth occasionally	219[1]	429	33.8
	Clean hands	58[1]	590	9.0
	Clean hands, different field	0	8,500	0.0
1927	Chewed barn-cured tobacco from mosaic-free crop of 1926	4	708	0.5
	Clean hands	1	711	0.1

1 Record made 48 days after setting; cultivation had been across plots.

Experimental Contamination of Workers' Hands. Experiments conducted between 1926 and 1928 (table 2) prove that tobacco plants may be infected with mosaic at pulling time if the

hands of the workers are dipped in a water decoction of barn-cured tobacco; if the worker chews barn-cured tobacco and occasionally spits on his hands or wipes his mouth occasionally; or if the puller chewed barn-cured tobacco and made no effort to contaminate his fingers, other than handling the dry tobacco.

Further proof of the part which handling dry, viruliferous tobacco and then pulling plants may play in field infection, was furnished by an experiment performed in 1937. Twists were made from tobacco infected the previous year with yellow mosaic, mosaic burn, and a non-burn green mosaic, respectively. Three pullers each crushed a piece of one of the twists in his hands, which had just been thoroly washed, dusted them off until they appeared free from bits of tobacco, and then pulled four lots of about 75 plants each which were numbered 1 to 4 and set in the field in that order with a machine setter. After growth commenced, a record was kept of the number of infected plants and the kind of mosaic, which appeared in each row. At each observation infected plants were removed. The results are given in table 3. Of the 878 plants which survived transplanting, two hundred and sixty-nine, or 30.6 percent, developed mosaic. In all instances but one the mosaic which developed was of the same kind as that contained in the twist handled by the man who pulled the plants. If each puller had continued to pull sufficient plants for one acre and no further infection had occurred, which is unlikely, over 1.2 percent of the plants set in the 3 acres would have developed mosaic soon after setting, as a result of each puller contaminating his hands once. Fifteen days after setting, 22 mosaic plants were found in the small portion of the bed from which the plants were pulled but none were found in the remainder of the bed. In this experiment where there appeared to be little if any field spread, mosaic plants were found 38 days after setting. These were small plants which started growth slowly and appeared to have been infected at pulling time. This is a longer incubation period than is usual with tobacco mosaic but in small, slow-growing field plants symptoms are difficult to see until growth commences. The drop off in infection as the virus wore off the fingers is also worthy of note.

It is generally assumed that washing the hands with soap and water is sufficient to remove virus from the hands if they are con-

taminated. This conclusion is usually based on inoculation of a few plants following washing. The writers are gradually coming to the conclusion that it is an extremely difficult matter to completely remove virus from the rough hands of workmen who handle viruliferous tobacco constantly. It seems entirely probable that low percentages of infection in fields where all known precautions have been taken may be caused by the gradual wearing off of virus embedded in the rough skin of the hands of the pullers or setters.

The objection has been raised (14) that "it is, of course, quite impossible to judge from such trials (intentional contamination of hands) as to how much infection of this type actually results under field conditions." This is hardly a valid criticism for it has proved to be a simple matter to raise beds of plants entirely free from

Table 3. Infection from hands of pullers on which contaminated dry tobacco was rubbed. Each of 3 men crushed a piece of contaminated twist tobacco in his dry hands, brushed them off, and then pulled four lots of tobacco which were set in the order pulled, on June 2, 1937, with a machine setter.

Row no.	Order of pulling	Number of infected plants found and removed on 6/18	6/21	6/25	6/28	7/7	7/10	Mosaic plants	Total plants	Percent mosaic	Kind of Mosaic: On the hands	Kind of Mosaic: In the field
121	1st	35	5	1	3	2	0	46	76	60.5	Yellow	Yellow
122	2nd	23	4	3	3	1	0	34	76	44.7	Yellow	Yellow
123	3rd	6	1	0	2	3	0	12	74	16.2	Yellow	Yellow
124	4th	2	1	0	1	0	1[1]	5	75	6.7	Yellow	Yellow
125	1st	40	6	0	0	0	1	47	73	64.4	Burn	Burn
126	2nd	13	3	2	2	2	1	23	74	31.1	Burn	Burn
127	3rd	5	1	0	0	0	0	6	71	8.4	Burn	Burn
128	4th	2	0	1	1	0	0	4	74	5.4	Burn	Burn
129	1st	34	3	2	8	2	0	49	71	69.0	Green	Green
130	2nd	11	3	0	4	2	2	22	70	31.4	Green	Green
131	3rd	5	4	1	6	0	1	17	73	23.3	Green	Green
132	4th	4	0	0	0	0	1	5	71	7.0	Green	Green
133		0	0	0	0	0		0	72	0.0	None	None
134		0	0	0	0	0		0	74	0.0	None	None

1 Mosaic burn.

mosaic year after year. Soil contamination can be eliminated by planting in a field which has not grown tobacco for years. Plants pulled and set with clean hands remain mosaic free for weeks, but plants pulled by men whose hands are contaminated with virus from handling barn-cured tobacco regularly have some mosaic. In the type of experiment reported in table 3 where three different strains of mosaic were used, each easily recognizable, mosaic infection could easily be traced to its true source. Each year many

farmers in Kentucky carry on, unconsciously, well-conducted tests which almost certainly prove that infection arises from the hands of the worker contaminated from handling barn-cured tobacco since all other known sources of infection are eliminated by their routine practices (table 4).

Table 4. Extent of infection of tobacco plants pulled and set by men some of whom used manufactured tobacco while pulling and setting, and some who used barn-cured tobacco. All plants were pulled from the same plant bed and all the plots or fields were set from first pulling, on a farm in Todd County. 1937.

Field	Number of plants			Percent of mosaic plants	Tobacco chewed by pullers and setters
	With mosaic	With mosaic burn	Healthy		
1	1	0	540	0.2	Manufactured tobacco
2	0	0	640	0.0	Manufactured tobacco
3	0	0	600	0.0	Manufactured tobacco
4a, Rows 1-50	15	3	10,689	0.2	Manufactured tobacco[2]
4b, Rows 51-89	354	350	7,803	8.3	Barn cured
5	20	0	300	6.3	Barn cured
6	187[1]		1,151	14.0	Barn cured

1 Mosaic and mosaic burn. Large field but only 1,338 plants counted.
2 Field 4 not cultivated for 11 years previously. Fields 1-2-3-5 in tobacco 3 or 4 years previously.

In 1936, thru accident, a well-conducted experiment was performed on the Experiment Station farm which illustrates the part which handling viruliferous tobacco may play in field infection. Two men pulled plants for a planting comprising, in all, 13,500 plants. When they were informed that they had pulled all the plants necessary to complete the planting, which was the last for the season, they went to the barn where one of them had placed a twist of barn-cured tobacco. He took a bite of it and after a time was told that there were not enough plants. Without washing, they went back to the plant bed and pulled a small lot of plants which were taken immediately to the field and set. They continued pulling until a sufficient number had been pulled to complete the planting. At the first mosaic count 20 days later, 18 mosaic plants were found in 8 rows. The remainder of the field was free from mosaic. With one exception the affected plants were either all even numbered or all odd numbered, where two or more

mosaic plants were found in a row, indicating that one man on the setter set the infected plants pulled by the man who chewed, while the other set uninfected ones.

Inquiry as to the source of these infections brought out the story just told. The mosaic plants were all affected with a severe burning type of mosaic. Further inquiry proved that the men had saved their chewing tobacco from a plot inoculated the previous summer with a burning strain of the virus. There appeared to be

Table 5. Mosaic in plantings on the Experiment Station farm over a 16-year period. The counts during the first three years are typical of those in previous years before control measures were initiated. From 1926 to 1937 the men were furnished with chewing tobacco believed to be mosaic free.

Year	Tobacco chewed by workers	Plants set	Mosaic plants at 3 to 4 weeks	
			Number	Percent
1922	Barn cured	14,000	1,260	9.00
1923	Barn cured	14,000	840	6.00
1924	Barn cured	14,000	1,218	8.70
1925	Commercial plug and natural leaf 5 years old	14,000	294	2.10
1926	Sterilized twist and plug	14,000	62	0.44
1927	Sterilized twist and plug	70,000	35	0.05
1928	Sterilized twist and plug	39,780	8	0.02
1929	Sterilized twist and plug	30,000	3	0.01
1930	Sterilized twist and plug	57,355	94	0.16
1931	Unsterilized Star plug	66,600	5	0.01
1932	Unsterilized Star plug	65,369	47	0.07
1933	Unsterilized Star plug	52,383	665[1]	1.27
1934	Sterilized and unsterilized Star plug	50,846	64	0.13
1935	Unsterilized Star plug	56,873	61	0.10
1936	Unsterilized Star plug	13,500	18[2]	0.13
1936	Unsterilized Star plug	12,800	38	0.30
1937	Dry air sterilized barn-cured tobacco	14,624	2	0.01
1937	Dry air sterilized barn-cured tobacco	15,542	21	0.14

1 Count made 40 days after setting and after cultivation and hoeing. Beds were very weedy. Men weeded who were in the habit of chewing barn-cured tobacco but did not use it while weeding. At first cultivation, many plants were covered with soil. These were uncovered by the men while hoeing. In one planting of over 13,000 plants ¼ of the mosaic plants were in 4 rows.

2 The mosaic plants were all mosaic burn and were traced to one man who handled and chewed tobacco from a mosaic-burn plot of the previous year.

no doubt that the 18 plants had become infected as the result of this man handling viruliferous tobacco for this short period.

Control of Tobacco Mosaic. Since 1926 mosaic has been controlled fairly effectively on the Station farm using the simple

precautions of burning or steaming the beds thoroly to reduce weeding, having men weed who do not use tobacco, and having the pullers and setters wash their hands and use mosaic-free tobacco (table 5).

During the past ten years instructions on mosaic control based on prevention of infection from the contaminated hands of workers who chew or smoke tobacco, have been given to individual farmers and to tobacco growers in general thru the press and extension service in Kentucky (23), and more recently to the press generally by the United States Department of Agriculture (19). Intelligent farmers recognize very quickly the importance of chewing and smoking tobacco as sources of infection and many have now put mosaic control into successful practice on their farms.

Examples of successful mosaic control over a ten-year or longer period on four farms in widely separated parts of Kentucky are given in table 6. At Greenville and Campbellsville soil experiment fields mosaic control has been nearly perfect. At Mayfield control has been successful where precautions were followed but in years when no precautions were taken there was a great deal of mosaic. The man who cared for this field from 1927 to 1933 was never convinced of the necessity of taking precautions against mosaic and only took them when he was furnished with sterile tobacco and then was not careful to wash his hands before beginning operations in the bed and field. Since employing another man who does not use tobacco and realizes the necessity of precautions against mosaic infection, mosaic has ceased to be a problem on this field. At Princeton a crew of men most of whom chew barn-cured tobacco, pulled and set plants. They use none during these operations and wash their hands in soap and water before commencing operations. Mosaic has been successfully controlled at Princeton altho not eliminated completely, perhaps because no precautions were taken during the summer to prevent infection from the worker's hands.

A certain religious sect in Kentucky prohibits its members from using tobacco in any form. Fields of dark tobacco grown by members of this sect were found in 1928 to be entirely free from mosaic while their neighbors who used tobacco had the usual amounts of mosaic.

Mr. Harry Campbell of Ridgetown, Ontario, Canada, a representative of a tobacco company which contracts with farmers in the district to raise tobacco and who, consequently, has considerable supervision over the handling of the crops, stated to the senior writer in 1937 that he insisted that growers who had much mosaic one year take precautions necessary to raise tobacco relatively free from mosaic the next year before a contract could be signed. In addition to thoro clean-up about the plant-bed site, he furnished

Table 6. Amount of mosaic in plantings a month or more after setting, on the Campbellsville, Greenville, Princeton and Mayfield Experiment Fields.

		Healthy Plants	Mosaic Plants	Percent
Campbellsville				
1927-1933	No tobacco used by workers	42,000	0	0.0
1934	Plants from Station farm, Lexington, precautions taken in pulling	6,630	2	0.03
1935	Plants from Lexington; no record of pullers who chewed barn-cured tobacco washing hands	6,600	145	2.2
1936	Plants from Lexington. Precautions taken	6,600	0	0.0
Greenville				
1925-1937	Two men smoke Prince Albert or Granger	50,673	10	0.02
Princeton				
1926-1937	Pullers and setters washed hands and did not use tobacco	98,477	147	0.15[2]
Mayfield				
7-13-25	1 man, no tobacco used	2,520	0	0.0
7-19-26	1 man, chewed Apple Sun-cured plug	2,520	0	0.0
8-26-27	3 men, 2 chewed barn-cured tobacco	1,487	1,033	41.0
8-8-28	No record	2,369	151	6.0
7-14-29	1 man, smoked and chewed sterilized fire-cured tobacco. 2nd year in tobacco	2,569	31	1.2
7-15-30	Smoked barn-cured tobacco but not during operations, washed hands in creek, without soap, before pulling	2,494	26	1.0
8-15-31	Chewed barn-cured tobacco	1,900	626	24.8
7-4-32	Chewed sterilized Burley, 2nd year in tobacco	2,517	3	.1
8-12-33	Chewed sterile tobacco	1,933	11	0.6
8-15-34	Another man employed, uses no tobacco	2,520	0	0.0
8-14-35	Man uses no tobacco	2,520	1	0.04
8-17-36	Man uses no tobacco	2,500	1[1]	0.04
Summary	Men used sterile or manufactured tobacco	202,059	153	0.08
	Men chewed barn-cured tobacco	12,356	1,955	13.7[2]

1 One mosaic observed early in summer not removed. Mosaic had spread to several others in same row.

2 Includes some field spread.

the growers with tobacco which he knew to be free from mosaic, for their personal use, and insisted on their roguing the few mosaic plants (less than .1 percent) which might appear. He stated that personally-used tobacco appeared to be the principal source of mosaic in the Harrow section in the types of tobacco with which he worked.

Field Surveys. In 1936 a field survey of mosaic was made in August and September, by the junior author, on farms picked at random. The results are given in table 7. The amount of mosaic varied greatly on adjoining farms and even in different fields on the same farms, under apparently similar conditions. Usually it was possible to explain such discrepancies by carefully questioning the grower or his workmen. A few examples from table 7 will illustrate. Grower 6 had 3 adjoining fields with 3, 4.2 and 27 percent mosaic. The workmen had been cautioned not to use barn-cured tobacco but one used some while pulling and setting the first 2 fields. After fields *a* and *b* were set, it was necessary to wait about 10 days until the plants left in the beds were large enough to set field *c*. This field set from the same beds from which *a* and *b* were set had 27 percent mosaic, evidently because of plant-bed infection which occurred at first pulling. Grower 7 set field *a* (3.2 percent mosaic) from his own bed and observed precautions to prevent infection from barn-cured tobacco. He set field *b* (33.3 percent mosaic) from the beds of grower 6 after the latter was thru setting. Grower 8 set all his crop of about 8 acres, except the last 25 rows at the end of the field, with plants from his own bed. He smoked manufactured cigarettes and did not use barn-cured tobacco. This portion of his crop had .6 percent mosaic and the 25 rows set with plants from his brother-in-law's bed, who chews barn-cured tobacco, had 25 percent mosaic. Grower 11 has successfully controlled mosaic for 3 years by forbidding the use of barn-cured tobacco and careful supervision of his workmen at setting time. In 1936 he set most of his crop from his own beds and at harvest had 1.1 percent mosaic. One field was nearly destroyed by wireworms and he reset this with plants from a bed of a neighbor who chewed barn-cured tobacco while pulling plants. He had 10.7 percent mosaic in this field. Thirty-three and 34 are adjoining farms and their

Table 7. Mosaic in tobacco fields in Kentucky in 1936. Fields were not in tobacco the previous year, except where indicated. Data between horizontal lines are from farms in the same neighborhood.

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
1	Todd	dark fired	46.6	Sept. 7	Chewed barn-cured tobacco.
2 (a)	Todd	dark air-cured	18.0	Aug. 20	Chewed barn-cured tobacco.
(b)	Todd	dark air-cured	29.0	Aug. 20	Chewed barn-cured tobacco.
3 (a)	Todd	dark air-cured	21.4	Sept. 11	Chewed barn-cured tobacco.
(b)	Todd	dark fired	34.3	Aug. 28	Chewed barn-cured tobacco.
4	Todd	dark fired	.5	Aug. 28	Did not chew.
5	Todd	dark fired	4.8	Aug. 28	Did not chew but got some plants from neighbor.
6 (a)[1]	Todd	dark fired	3.0	Aug. 19	Cautioned men not to chew.
(b)	Todd	dark fired	4.2	Aug. 19	Grower thinks one man chewed.
(c)	Todd	dark fired	27.0	Aug. 19	Set after bed had been pulled over once.
7 (a)[1]	Todd	dark fired	3.2	Aug. 19	Smokes cigars.
(b)	Todd	dark fired	33.3	Aug. 19	Plants from 6 after latter was thru setting.
8 (a)	Todd	dark fired	.6	Sept. 10	Did not chew.
(b)	Todd	dark fired	25.0	Sept. 10	Plants from brother-in-law who chewed barn-cured tobacco.
9	Todd	dark fired	18.0	Sept. 10	Chewed barn-cured tobacco.
10	Todd	dark fired	34.9	Aug. 30	Chewed barn-cured tobacco.
11 (a)[1]	Todd	dark fired	1.1	Sept. 7	Did not use tobacco.
(b)	Todd	dark fired	10.7	Sept. 7	Got plants from neighbor who chewed barn-cured tobacco.
12	Todd	dark fired	38.0	Aug. 5	Chews barn-cured tobacco.
13	Todd	dark fired	4.4	Sept. 7	Did not chew barn-cured tobacco.
14	Todd	dark fired	28.5	Aug. 17	Chewed barn-cured tobacco
15	Christian	dark fired	12.5	Aug. 27	Field in tobacco 1935; chewed barn-cured tobacco.
16	Montgomery, Tenn.	dark fired	61.5	Aug. 27	Chewed barn-cured tobacco.

[1] Attempted to follow directions given for controlling mosaic.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
17 (a)	Todd	dark fired	9.7	Aug. 24	Chewed barn-cured tobacco.
(b)	Todd	air-cured	10.4	Aug. 24	Chewed barn-cured tobacco.
(c)	Todd	Burley	11.3	Aug. 24	Chewed barn-cured tobacco.
18 (a)	Todd	Burley	12.5	Aug. 24	Chewed barn-cured tobacco.
(b)	Todd	dark air-cured	16.6	Aug. 24	Chewed barn-cured tobacco.
19	Todd	dark fired	11.6	Aug. 6	Cautioned men not to chew.
20	Todd	dark fired	13.6	Aug. 14	Cautioned men not to chew.
21	Todd	dark fired	57.9	Aug. 27	Chewed barn-cured tobacco.
22 (a)	Todd	dark air-cured	6.6	Aug. 27	Did not chew.
(b)	Todd	dark air-cured	14.0	Aug. 27	Set and cared for by cropper after his own was set. Latter probably used barn-cured tobacco.
(c)	Todd	dark fired	5.1	Sept. 11	Did not chew
23 (a)	Todd	dark fired	59.1	Aug. 20	Did not chew. Did much resetting after neighbors who chewed barn-cured tobacco had pulled plants from his bed.
(b)	Todd	dark air-cured	51.8	Aug. 20	Did not chew. Did much resetting after neighbors who chewed barn-cured tobacco had pulled plants from his bed.
(c)	Todd	dark air-cured	65.0	Aug. 20	Late setting after beds were pulled over.
(d)	Todd	dark fired	82.0	Aug. 20	Late setting after beds were pulled over.
24	Todd	dark fired	3.5	Aug. 27	Did not chew.
25 (a)	Todd	dark air-cured	33.9	Aug. 20	Chewed barn-cured tobacco.
(b)	Todd	Burley	22.6	Aug. 20	Chewed barn-cured tobacco.
26	Logan	dark air-cured	44.5	Aug. 20	Chewed barn-cured tobacco.
27 (a)	Todd	dark air-cured	81.5	Aug. 6	Watered bed with tobacco decoction.
(b)	Todd	dark fired	13.6	Aug. 6	Bed not watered with tobacco decoction. Chewed barn-cured. Both fields in tobacco for several years.
28	Todd	dark fired	90.0	Sept. 18	Chewed barn-cured tobacco. Had to reset several times.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
29	Todd	dark fired	32.2	Sept. 14	Chewed barn-cured tobacco.
30	Todd	dark fired	.1	Sept. 14	Did not chew.
31	Todd	dark fired	.8	Aug. 30	Belongs to religious sect that forbids use of tobacco.
32	Todd	dark fired	6.7	Aug. 30	Chewed barn-cured tobacco.
33[1]	Todd	dark fired	51.3	Sept. 18	Did not chew, but got 75 percent of his plants from 3 neighbors after they were thru setting.
34 (a)	Todd	dark fired	2.5	Sept. 18	Smokes cigarettes.
(b)	Todd	dark fired	31.5	Sept. 18	Smoked barn-cured tobacco in a pipe. Beds of 33, 34-a, and 34-b contiguous.
35 (a)	Todd	dark fired	25.3	Aug. 19	Chewed barn-cured tobacco.
(b)	Todd	Burley	16.5	Aug. 19	Chewed barn-cured tobacco.
36	Todd	dark fired	.0	Aug. 19	Smoked manufactured tobacco (Stud) in pipe.
37	Todd	dark fired	28.0	Sept. 7	Chewed barn-cured tobacco.
38 (a)	Todd	dark fired	59.5	Aug. 28	Chewed barn-cured tobacco.
(b)	Todd	dark fired	64.3	Aug. 28	Chewed barn-cured tobacco.
39	Todd	dark fired	48.2	Aug. 28	Chewed barn-cured tobacco.
40 (a)	Todd	dark fired	2.8	Aug. 17	One man may have chewed barn-cured tobacco.
(b)	Todd	dark fired	8.8	Sept. 7	One man chewed barn-cured tobacco.
41	Todd	dark fired	46.5	Aug. 18	Chewed barn-cured tobacco.
42 (a)	Todd	dark fired	16.8	Aug. 18	Chewed barn-cured tobacco.
(b)	Todd	dark fired	43.0	Aug. 18	Plants grown on old bed site where tobacco plants were 5 ft. tall when plowed under in late fall.
43[1]	Todd	dark fired	0.0	Aug. 30	Did not use tobacco.
44 (a)	Todd	Burley	1.2	Aug. 19	Did not use tobacco.
(b)	Todd	dark fired	25.5	Aug. 19	Chewed barn-cured tobacco.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
45	Todd	dark fired	0.0	Aug. 24	Chewed his own barn-cured tobacco but says he has had little or no mosaic for years.
46[1]	Todd	dark fired	0.0	Aug. 24	Did not use tobacco.
47[1]	Logan	dark fired	3.2	Aug. 20	Did not use tobacco. Wrapped one lot of plants in moist burlap bags, previously used to wrap damaged tobacco.
48	Logan	dark air-cured	40.0	Aug. 20	Chewed barn-cured tobacco.
49[1]	Logan	dark air-cured	.6	Aug. 20	Did not use tobacco.
50[1]	Logan	dark air-cured	1.6	Aug. 20	Brother to 48. Did not use tobacco.
51	Logan	dark air-cured	24.2	Sept. 7	Chewed barn-cured tobacco.
52	Logan	dark air-cured	90.0	Aug. 20	Watered plant bed with tobacco decoction.
53 (a)	Logan	dark fired	27.9	Aug. 22	Crew smoked barn-cured tobacco; field in tobacco 1935.
(b)	Logan	dark air-cured	38.7	Aug. 22	Crew smoked barn-cured tobacco; field in tobacco 1935.
54 (a)	Logan	dark fired	61.7	Aug. 22	Set by 53's crew. Plants mostly from 53.
(b)	Logan	dark air-cured	38.6	Aug. 22	Set by 53's crew. Plants mostly from 53.
55	Logan	dark air-cured	43.2	Aug. 27	Chewed barn-cured tobacco.
56	Logan	dark fired	46.4	Aug. 22	Chewed barn-cured tobacco. Field not in tobacco for at least 15 years.
57 (a)	Logan	dark fired	25 9	Aug. 4	Chewed and smoked barn-cured tobacco.
(b)	Logan	dark fired	28.2	Aug. 15	Chewed and smoked barn-cured tobacco.
58	Logan	dark fired	80.4	Aug. 3	Chewed and smoked barn-cured tobacco.
59	Logan	dark fired	23.2	Aug. 15	Chewed and smoked barn-cured tobacco.
60	Logan	dark fired	29.5	Aug. 22	Chewed and smoked barn-cured tobacco.
61	Logan	dark fired	5.0	Aug. 22	Did not chew. Man who chewed helped him for half day during setting.
62	Logan	dark fired	16.8	Aug. 29	Chewed barn-cured tobacco.
63	Logan	dark fired	39.8	Aug. 22	Chewed and smoked barn-cured tobacco.
64	Logan	dark fired	27.6	Aug. 15	Chewed and smoked barn-cured tobacco.
65	Logan	dark fired	61.2	Aug. 22	Chewed barn-cured tobacco.

Table 7. (Continued)

Grower	County	Type of tobacco	Percent mosaic present	Date of observation	Habits of grower and notes
66	Logan	dark fired	70.5	Aug. 15	Chewed barn-cured tobacco.
67	Logan	dark air-cured	58.6	Aug. 29	Chewed barn-cured tobacco.
68 (a)	Logan	dark air-cured	85.4	Aug. 22	Chewed and smoked barn-cured tobacco.
(b)	Logan	dark fired	80.6	Aug. 22	Chewed and smoked barn-cured tobacco.
69	Logan	dark fired	70.6	Aug. 3	Chewed barn-cured tobacco.
70	Logan	dark fired	84.0	Aug. 3	Chewed barn-cured tobacco.
71	Logan	dark fired	36.0	Sept. 11	Chewed barn-cured tobacco.
72	Daviess	dark air-cured	65.0	Aug. 11	Chewed barn-cured tobacco.
73[1]	Daviess	dark air-cured	2.0	Aug. 11	Did not chew. Brother of 72.
74	Daviess	dark air-cured	57.3	Aug. 11	Chewed barn-cured tobacco.
75	Caldwell	dark fire-cured	25.5	Sept. 4	Smoked cigarettes made of barn-cured tobacco.
76	Caldwell	dark fire-cured	28.0	Sept. 4	Chewed barn-cured tobacco.
Princeton Sub-station[1]	Caldwell	dark fire-cured	.6	Sept. 4	Did not chew barn-cured tobacco.
77 (a)	Christian	dark fire-cured	12.0	Sept. 9	Chewed barn-cured tobacco.
(b)	Christian	dark fire-cured	3.0	Sept. 9	Handled by tenant who did not use barn-cured tobacco.
78	Christian	dark fired	1.0	Sept. 9	Did not chew barn-cured; occasionally smokes barn-cured 3-yr.-old Burley in pipe.
79	Logan	dark fired	38.9	Aug. 25	One man who pulled most of plants chewed barn-cured tobacco.
80	Logan	dark fired	20.5	Aug. 25	Chewed barn-cured tobacco.
81	Logan	dark fired	.7	Aug. 25	Did not use tobacco.
82	Logan	dark fired	6.0	Aug. 25	Did not use tobacco.
83[1]	Cheatham, Tenn.	dark fired	.5	Sept. 15	Rogued mosaic plants as soon as they appeared.
84[1]	Cheatham, Tenn.	dark fired	1.5	Sept. 15	Son did all handling of mosaics. Nobody else allowed to touch them.

plant beds were contiguous. Thirty-three did not allow his workmen to use barn-cured tobacco but on account of drouth, 80 percent of his first setting died. He reset with plants from the beds of 3 neighbors, all of whom used barn-cured tobacco. He had 51.3 percent mosaic. Thirty-four had 2 fields handled by 2 tenants each of whom had his own bed. Field *a,* cared for by a man who used commercial cigarettes only, had 2.5 percent mosaic, while field *b,* cared for by a man who smoked barn-cured tobacco in a pipe, had 31.5 percent. The same cropping system was used by 33 and 34 and the fields were close to each other. Thirty-five and 36 are adjoining farms and their beds were parallel. The former, whose workmen used barn-cured tobacco, had 25.3 and 16.5 percent mosaic, respectively, in dark fire-cured and Burley tobacco. The latter, just over the fence, who smoked granulated manufactured tobacco in a pipe, had no mosaic at harvest. Seventy-two and 73 are brothers whose farms are in the same neighborhood. Seventy-two, who chews barn-cured tobacco, had 65 percent mosaic while his brother, who did not use tobacco, had 2 percent. On 13, or 15.5 percent, of the 84 farms studied, the grower was attempting to control mosaic under the direction of the county agent or crop specialist. Considering the fact that the observations were all made near cutting time, the degree of control obtained is remarkable.

Only three of the fields studied had been in tobacco the previous year. This fact eliminates nearly completely the possibility of soil carry-over. Nevertheless the amount and distribution of mosaic are probably as great as is commonly found in regions where tobacco commonly follows tobacco, or greater. The fact that, where efforts were made to control mosaic by preventing infection from the hands of the workers, the disease was largely prevented tends to prove that contaminated hands were the principal source of infection where it occurred.

In 1937 a similar survey was made in several counties in western Kentucky just previous to harvest. The observations made on 162 fields on which tobacco had not been grown in 1936 were arranged in three groups according to the conduct of the workers in the use of tobacco while tending plant beds and setting plants. The men of the first group chewed and smoked barn-cured tobacco; those of the second group were men who ordinarily used barn-

cured tobacco but changed to manufactured tobacco when handling tobacco plants, and men who habitually used manufactured tobacco or manufactured cigarettes; while those of the third group claimed they used no tobacco. Table 8 and figure 1 show the re-

Table 8. Incidence of mosaic as related to use of viruliferous tobacco by workers, observed in 162 fields, in 1937.

Barn-cured tobacco used		No barn-cured tobacco used		
			Manufactured tobacco or cigarettes used	No tobacco used
Percent of mosaic plants	No. of fields	Percent of mosaic plants	No. of fields	No. of fields
0.1	3	0.00	5	14
1	2	0.01	2	—
5	1	0.04	1	1
6	1	0.05	1	—
7	3	0.10	4	4
8	5	0.20	1	1
9	4	0.30	4	5
10	3	0.40	1	1
11	4	0.70	1	—
12	6	1.00	2	2
13	4	1.10	—	2
14	2	1.40	2	—
15	1	1.50	3	—
16	4	1.80	5	—
17	3	2.40	2	—
18	3	2.50	1	—
19	3	2.60	1	1
20	3	3.40	1	—
21	2	3.70	—	1
22	2	4.00	1	—
23	2	4.20	—	1
24	2	5.00	2	—
29	2	5.10	1	—
30	1	6.00	2	—
32	2	6.20	1	—
33	2			
35	3			
36	1			
38	2			
39	1			
41	1			
42	1			
46	1			
55	1			
60	1			
67	1			
83	1			
90	1			
Total	85		44	33

Table 9. Range and average percent of mosaic in fields (a) where attempts were made to control tobacco mosaic by prohibiting the use of barn-cured tobacco by workers in the bed and at setting; (b) where no attempt was made to control mosaic but no barn-cured tobacco was used thruout the season, and (c) in fields where barn-cured tobacco was smoked or chewed by the workers thruout the season. Records were made shortly before harvest, 1937.

	Number of fields	Range of mosaic percent	Av. mosaic percent
Use of barn-cured tobacco prohibited	31	0.0— 9.0	2.5
No attempt to control but workmen either used no tobacco or used manufactured tobacco thruout the season	41	0.0— 4.2	0.46
Workmen chewed or smoked barn-cured tobacco[1]	31	6.7—83.0	23.0

1 These are the first 31 fields recorded where workmen used barn-cured tobacco.

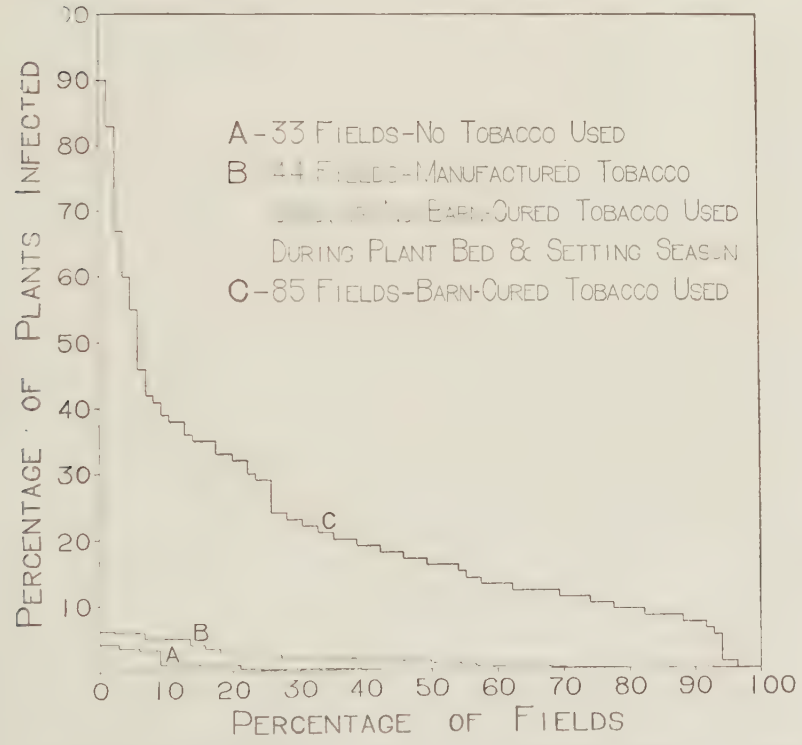


Figure 1. Incidence of mosaic as related to use of viruliferous tobacco by workers, observed in 162 fields, in 1937.

sults. The lower curve (A), in the figure, is based on 33 fields handled by men who used no tobacco thruout the season. The area within the curve when compared with the entire square represents the proportion of the crop, on an average (.55 percent), which might be expected to be infected with mosaic at cutting time if all growers in an area used no tobacco thruout the season. The middle curve (B) is based on 44 fields handled by men who used manufactured tobacco or were in the habit of using barn-cured tobacco but claimed to have used none while working in the plant bed or setting plants. The small average amount of mosaic (1.6 percent) in these fields may have originated from the hands of the workers which were not thoroughly washed, or which may have become recontaminated from bits of tobacco still in their pockets or infection may have occurred from the hands of men who used barn-cured tobacco during the summer. The upper curve (C) is based on 85 fields cared for by men who used barn-cured tobacco for chewing or smoking thruout the season. The portion of the entire square (20.9 percent) bounded by this curve represents the part, on an average, of the tobacco which may be expected to be infected with mosaic by cutting time if the fields under consideration have been cared for by men who chew or smoke barn-cured tobacco. These results seem to give proof that in fields where tobacco does not follow tobacco the principal source of mosaic infection is barn-cured tobacco used by workmen.

On 11 fields tobacco followed tobacco and on three of these fields tobacco plants lived thru the mild winter of 1936-37. Some of these plants were found to have mosaic in the spring of 1937 and seemed to have been a source of infection for plants set in 1937, because on two of the farms where 14.7 and 17 percent mosaic was found following tobacco similarly treated fields not in tobacco the previous year had .4 and .1 percent mosaic, respectively. On the other fields the amount of mosaic was large or small depending upon the habits of the workmen with respect to the use of tobacco.

Twist Chewing Tobacco. In 1937, 35 samples of twist chewing tobacco, prepared from barn-cured tobacco, were collected from as many tobacco growers. Samples of these weighing .9 gram were ground in a mortar, 9 c.c. of water was added and the tobacco was allowed to soak for 1 hour. Then inoculations were made on

Scotia bean leaves and on leaves of *Nicotiana glutinosa* and F_1 hybrids of it and White Burley tobacco. Thirty of these samples, or 85.7 percent, were found to carry the virus. It is obvious that the majority of tobacco growers who chew or smoke barn-cured tobacco while handling plants are also handling viruliferous tobacco.[1]

Manufactured Tobacco. Manufactured tobacco sometimes is viruliferous and has therefore been considered by some investigators to be a rather common source of infection but the facts so far obtained hardly justify this conclusion. In 1927, Valleau and Johnson (21) obtained the following results with 44 brands of tobacco tested:

Tobacco tested	Number of brands tested	Number of brands contaminated	Number of samples contaminated	Number of samples mosaic free
Plugs	23	4	10	33
Scrap	5	0	0	5
Twist	2	0	0	3
Snuff	1	0	0	1
Cigarettes	7	7	11	1
Granulated smoking	5	5	5	0
Plug cut	1	0	0	1
Total	44	16	26	44

These results proved that commercial tobaccos sometimes carry the virus but it was pointed out that, as only four brands of plug tobacco of 23 tested carried the virus, and three of twist, five of scrap, and one of snuff were found to be free, manufactured tobaccos were not likely to be common sources of infection.

In 1928, 15 brands of cigars were tested and 7 were found to carry the virus (5). The same year 11 brands of plug chewing tobacco and one lot of barn-cured tobacco were made into separate decoctions with water and the decoctions rubbed on approximately 60 plants each, which were then set in the field. Every fifth row of plants from the same bed was pulled and set with clean hands. Twenty-six days later the following results were obtained:

	No. of Plants		
	Set	Mosaic	Percent Mosaic
Brand A	60	6	10.0
Brand B	47	3	6 4
Other nine brands	496	0	0.0
Check plants, clean hands	375	0	0.0
Barn-cured tobacco	65	41	63.1

1 Pinckard has recently shown that the tobacco mosaic virus is not inactivated by a temperature of over 190° F. for 7 hours during flue curing, hence flue-cured tobacco may be a source of infection if it is used by growers while handling living plants. (Abst. in Phytopathology 28: Jan. 1938.)

These results demonstrated that not only were most of the brands of plug tobacco free from mosaic but where it was present the concentration was very low.

The same year 15 brands of smoking tobacco in cans were found to carry virus but it was difficult to contaminate the fingers by handling the tobacco because of the glycerine and other materials added or because of low virus concentration.

Busch and Wolf (6) studied 45 brands of manufactured tobacco including 10 of granulated pipe tobacco, 7 of cigarettes, 11 of snuff and 17 of chewing tobacco. Of the 45 brands studied only 2 brands of chewing tobacco and 2 of snuff caused mosaic. In 1937 J. Johnson (14) reported that cigars, cigarettes and pipe tobacco carried the virus but 10 brands of snuff and chewing tobacco were found to be free.

Because of results such as these, we have not hesitated to recommend the use of plug and twist tobacco for chewers, and the men have used manufactured plug (Star) on the Station farm several years while pulling and setting, with good results. We have good evidence that at least 2 brands of canned smoking tobacco are safe to use. The Greenville soil experiment field has been cared for for several years by two men who smoked Prince Albert and nothing else, until 1934 when they changed to Granger. They take no precautions to prevent mosaic in the plant bed and field except when extra help is hired and have never been troubled with mosaic except occasionally following a field meeting attended by tobacco users (table 6).

Cigarettes commonly carry the virus, but because of the cover of paper and the treatment of glycerine and other materials which the tobacco receives, there is little chance that one's fingers would become contaminated from them. Field observations where cigarettes were used by the worker, confirm this view. Granulated smoking tobaccos also carry the virus but do not seem to contaminate the hands while filling a pipe or rolling cigarettes.

Nine fields cared for by men who used manufactured granu-

lated smoking tobacco were observed when about ready to cut. The percentage of mosaic plants were as follows:

	Percent of mosaic plants
Brand A, 2 fields	0.0
Brand B, 1 field	0.0
Brand C, 3 fields, respectively	0.0 0.2 1.5
Brand D, 1 field	0.3
Brand not recorded, 2 fields, each	0.1

Fukushi (9), after a study of mosaic in commercial brands of pipe tobacco commonly smoked by Japanese tobacco growers, stated that "It is highly probable that tobacco growers may spread the mosaic disease of tobacco in the operations of transplanting, topping and weeding, etc. of the tobacco plants with hands contaminated with the virus during smoking the pipe tobacco."

The contention (14) that manufactured tobacco, because of blending, is more likely to contain virus than barn-cured tobacco, is hardly valid, for the manufacturing processes tend either to reduce actual virus concentration as in plug and twist tobacco or tend to greatly reduce the chance that the fingers of the workers will become contaminated, as cigarettes and pipe tobaccos. On farms where mosaic is constantly a problem it would be difficult to select cured tobacco for chewing or smoking which did not contain virus. Where but little mosaic is present from year to year but little infection would be expected from the use of the nearly virus-free tobacco used by the workers. Many brands of commercial tobacco have a very low virus concentration or none whatever because of the heating to which they are subjected altho the original tobacco may have been viruliferous because of blending.

Until proof has been produced that manufactured tobaccos are actually a common source of tobacco mosaic, they may be consid-

Table 10. Distribution of viruses in Physalis sp. and Solanum carolinense growing in grass plots on the Experiment Station farm.

	Plants
Total examined	633
No virus found	445
Tobacco mosaic	132
Etch	4
Cucumber mosaics	11
Ringspot	3
Virus not determined	38

Table 11. Distribution of tobacco mosaic in plantings on the Station farm, Lexington, 1930 to 1937, showing gradual increase in mosaic during the summer but satisfactory commercial control where men were required to wash their hands and use sterile tobacco or manufactured plug while pulling and setting. Tobacco had not been grown on the land for at least 4 years. Plant beds were mosaic free.

Year	1930	1931	1932	1933	1934	1935	1936	1937
Number of plants set	36,168	40,900	32,712	31,500	17,424	14,686	12,800	15,542
Number of mosaic plants, 1st count	35	2	24[1]	2	12	7	38[2]	21[5]
Number of mosaic plants, 2nd count	76	41	468	558	27[5]	10	—	14[5]
Number of mosaic plants, 3rd count	—	205	—	706	207[6]	—	—	19[5]
Number of mosaic plants, 4th count	—	—	—	—	—	—	—	12[5]
Percent of mosaic plants after topping	—	4.4	—	5.8	12.7	—	—	—
Percent of mosaic plants after cutting	.	—	31.0	—	—	1.4	.9[3]	.6[4]

[1] About ½ of these were resets, evidently pulled and set with contaminated hands.
[2] 18 from 1 chew of tobacco.
[3] Dry season; tobacco not topped until cutting time.
[4] 5,300 plants counted.
[5] Plants removed.
[6] In 108 rows.

ered relatively safe for use by workers in tobacco except while weeding or otherwise handling plants in the bed before pulling time.

LIVING PLANTS AS A SOURCE OF MOSAIC

Infected perennial weeds and overwintering annuals cannot be disregarded as possible sources of infection. Perennial solanaceous weeds growing in pastures or other grass plots in the vicinity of fields frequently set with tobacco are often found to be infected with the tobacco mosaic virus even tho the weeds may be several hundred feet from the tobacco fields (table 10). Each year mosaic-affected tobacco plants appear in the Station plantings which cannot be accounted for. For example, in 1934 the 27 mosaic plants found were rogued at the second count (table 11). At the time of the third inspection 21 days later, 207 mosaic plants were found, scattered at random in 108 rows. A similar condition existed in 1937 (table 11). The source of infection of these plants, which were distributed rather evenly over the field, is not known.

In all the plots on the Station farm cucumber mosaics, etch, veinbanding and ringspot are rather generally distributed thru the crop. These viruses, except veinbanding, are found in solanaceous weeds and are probably spread to tobacco from them. It is possible that the insects responsible for weed infection from tobacco may be responsible for some of this summer infection of tobacco with mosaic, altho workers may have been the source; and it is not impossible that during cultivation the tools may become contaminated from infected weeds in the field and spread the virus to tobacco. If infection occurs from weed hosts it is not extensive.

INSECT TRANSMISSION OF MOSAIC

The problem of insect transmission of tobacco mosaic has never been thoroly studied. Allard (2) demonstrated that the peach aphis (*Myzus persicae* Sulz) and other species of aphis could transmit a virus which he thought was that of tobacco mosaic, from tobacco to tobacco. Miss Hoggan (10), in a series of carefully conducted studies, demonstrated, she believed, that *Myzus persicae* is incapable of transmitting the tobacco mosaic virus, but regularly transmits the cucumber mosaic virus. She demonstrated, however, that three other species of aphis, *Macrosiphum solanifolii*, *Myzus cir-*

cumflexus and *M. pseudosolani* were each able to transmit the strain of tobacco mosaic studied, from tomatoes to tobacco but not from tobacco to tobacco. The strain of virus used was apparently an unusual one, for it caused systemic mosaic in tobacco and *Nicotinia glauca* but produced systemic necrosis in pepper and *Physalis pubescens.* In nearly all varieties of pepper most strains of the virus cause only mottle. The fact that Miss Hoggan demonstrated aphis transmission of two strains of the tobacco mosaic virus to tobacco proves that these species are carriers of the virus and makes it appear reasonable that in nature some species of aphids and perhaps other insects may play a part in dissemination of mosaic from tobacco to solanaceous weeds and from the weeds to an occasional tobacco plant even tho they do not transmit the disease from tobacco to tobacco in the field. In view of the fact that certain aphids become contaminated with the tobacco mosaic virus and are then capable of transmitting it to tobacco, it cannot be concluded that they play no part in initial field infection, as has been the tendency recently. A virus so readily transmitted mechanically as tobacco mosaic might well be introduced into tobacco fields from infected weeds by some of the biting insects which commonly visit tobacco.

Insect transmission, if it occurs, is probably a minor factor in outbreaks of mosaic, but it may eventually prove a constant source of trouble on farms where weeds are infected and where the grower is making every effort to eradicate the disease but finds it cropping out over the field in individual plants which may become centers of spread by other means.

CONTAMINATED SOIL NOT A COMMON SOURCE OF MOSAIC

In summarizing his investigations on mosaic, Mayer (17) stated in 1886 that "the dissemination of the disease-producing material must be looked for in the soil of tobacco plantations and hotbeds; because permanent plantations are particularly exposed to the disease. However, an instance of its transmission by soil has not been established."[1] Nevertheless he recommended a change in plant-bed soil where mosaic is a factor, roguing of plants in the field and complete removal of all mosaic plants from the field at

1 Translation by the authors.

the end of the season so that no mosaic material would remain on the land. This is perhaps the first suggestion in the literature that soil is a factor in carry-over but it should be remembered that it was not based on experimental or observational data.

In 1929 Johnson and Ogden (12) revived the theory of soil contamination as an explanation of initial infection of tobacco grown in fields where tobacco was heavily infected the year before. They gave no explanation for infection in fields set with tobacco for the first time and disregarded completely the part which man might play in causing initial infection in the plant bed and field while weeding and pulling plants, if his hands were contaminated with virus from chewing or smoking tobacco or from otherwise handling viruliferous material. They assumed that because mosaic virus could be obtained from about the dead roots of infected plants in the spring, this must be the chief source of mosaic in the field. The possibility that cucumber mosaic and other common virus diseases might be present in their plots and be mistaken for tobacco mosaic was not given consideration altho it was known at that time that cucumber mosaic was a common disease in tobacco fields located near garden plots (22, 20, 5). It has since been shown that cucumber mosaic was present in at least a portion of their plots and it was probably mistaken for tobacco mosaic in their studies on the effect of curing on the longevity of the tobacco virus (14). Johnson and Ogden proved beyond reasonable doubt that the tobacco mosaic virus can and does persist over winter in the dead roots of tobacco plants and can be recovered from adjacent soil in which visible roots are not present.

In 1937, J. Johnson again stressed soil contamination as a source of initial infection. In the annual report of the Wisconsin Agricultural Experiment Station, the statement is made that "Thus far there is known only one effective means of controlling mosaic, and that is to refrain from planting tobacco on heavily infested fields" (8). As Johnson's paper (14) was published at a time when an aggresive and successful mosaic-control program was under way in some of the southeastern tobacco-growing states, his statements need careful consideration. The field evidence given in his paper was observational and was collected between 1926 and 1932. It is

open to the same objection as the earlier observations of Johnson and Ogden, and in addition insufficient recognition was given to the possibility of spread during the summer by machinery used in cultivation and to the possibility of direct infection by man either as a result of handling an occasional infected plant and then handling healthy ones, or directly from hands contaminated by tobacco used for chewing or smoking, while hoeing, worming, etc. He states that "the present status may be well represented by Wolf's recent discussion of tobacco mosaic in the flue-cured tobacco district of the United States. In a three year survey it was found that the mosaic in 125 fields out of 229 examined could be traced to infested soil alone." By infested soil Wolf evidently meant a soil in which were present living infected roots, as he states (25) "mosaic virus may retain its infectivity in tobacco stubbles, as shown by the fact that in the spring mosaic suckers may develop on stubbles that have remained alive. In 125 of the 229 fields observed, the virus overwintered in tobacco stubbles." This certainly does not represent "the present status" in the more northern states where tobacco roots are killed by winter freezes. Neither is it in accord with the statement (14) that "some overwintering may occur in perennial hosts, or in tobacco or other annuals where killing frosts do not occur, but this potential source of infection is no longer regarded as of much importance by most investigators." Lehman's (15) field studies confirm Wolf's view as to the method of overwintering of the virus in North Carolina. Johnson states that Lehman (15) "apparently attaches somewhat less importance to direct infection from either the soil or the use of infected tobacco by workers, but finds high percentages of mosaic spread resulting from cultivation." Lehman's chief contribution, aside from demonstrating rapid field spread and its control by roguing, appeared to be that by eliminating the virus from the hands and clothes of workers, mosaic could easily be controlled even when tobacco was set in fields which had grown an infected crop the year before. Lehman states "The careless use of tobacco in chewing and smoking while handling young plants, as in weeding beds, etc. is responsible for initial infections which may develop to large proportions by harvest."

Johnson concludes "that the soil is a very common source of

primary infection." The reasons for this conclusion are as follows: "1. Previously infested fields regularly develop a considerably higher percentage of mosaic than do newer fields (table 2); 2, except for such mosaic as is plainly due to infection before or at the time of transplanting, the disease develops gradually in the field during the early growing season in the absence of other sources of infection and dissemination (table 1); and 3, the virus regularly persists in the field soil in sufficient quantity and for sufficient time to account for this infection (table 10)." A critical examination of these reasons shows that his conclusion cannot be accepted. Reason 1 is open to question in view of carefully conducted tests of Lehman which demonstrate clearly that heavily-infested fields may produce practically a virus-free crop the next year if certain simple precautions are taken to prevent initial infection by workmen and spread in the field by tools. It is open to further criticism that in Kentucky where tobacco rarely follows tobacco, mosaic is often a serious problem in fields set to tobacco for the first time (tables 5, 7 and 9). Further, he apparently gave no consideration to the possibility of infection while weeding, pulling, and setting. Reason 2: Lehman has shown that where care is not taken to prevent spread in the field, there is a gradual increase in mosaic during the summer, but where spread is prevented by roguing before cultivation, gradual increase does not occur. The writers have some evidence of a gradual building up of infection in fields not in tobacco before and where the first mosaic plants were removed soon after growth commenced. Wolf (25 p. 164) considered that the gradual increase of mosaic during the summer was not due to soil contamination but was the result of spread by man himself in caring for the crop. Johnson assumes "the absence of other sources of infection and dissemination." Reason 3: While the virus may persist in the soil from one crop to the time of setting the next crop, no one has produced acceptable evidence that more than an extremely low percentage of mosaic ever actually originates directly from this source; and evidence cannot be forthcoming on this point until all chance of infection from the bed, during pulling and setting, and spread by operations in the field are eliminated, and the study is confined entirely to the tobacco mosaic virus.

Wolf made a careful study of the epiphytology of tobacco mosaic in plant beds and fields in North Carolina covering the years 1928, 1929, and 1930 (25). He observed early is the course of his study that mosaic occurs in the seed bed on seedlings of sufficient size for transplanting. He found infected seedlings in 108 of 584 beds examined. This seems to be sufficient evidence to disprove Johnson's claim (14) that "visible symptoms of mosaic are rare even on infected seedlings in seed beds at the time of transplanting." Infection in only 1 of the 108 beds could possibly be attributed to infected seed-bed soil as but one bed was located on an old site. Wolf concluded that manufactured tobacco used by the grower constituted the most probable source of the introduction of the virus in 105 of 108 seed beds in which infection was found. If the 584 beds are representative, then infection in about 20 percent of the fields in North Carolina can be explained by infection originating from the hands of the workmen in the beds before pulling commences.

Wolf made observations on the source of mosaic in the field in 229 fields examined during three seasons. He concluded that infection could be traced to seed beds alone in 24, to infected field soil alone (living or partially living overwintered tobacco stubble) in 125 and to both diseased seedlings and infected soil in 63. In 17 the source of the inoculum could not be determined, altho he suggested that it might have been the hands of the workers which had become contaminated thru their having used manufactured tobacco. His conclusions cannot be accepted for the reason that the criteria used to determine sources of field infection left out what appears to be the most common source of infection; namely, infection while pulling and setting. It seems obvious that, if 20 percent of the beds were infected before pulling, plants pulled from mosaic-free beds could become infected from the same source that caused infection in other beds. He states "infected soils alone were regarded as the source when the seed beds from which the crop was planted were mosaic free, and where such fields had borne a mosaic-affected crop during the previous year." Infection in the 125 fields attributed to soil alone (overwintering plants), and the 17 which

could not be determined, may have come from the hands of the men who pulled and set the plants, altho it is entirely probable that some infection in the former may have originated from overwintered plants. It should be kept in mind that beds may be cared for by men who for one reason or another do not contaminate any plants, but at pulling time other laborers may be hired for pulling and setting who use tobacco in one form or another and who may therefore infect plants while pulling and setting them. Every plant set in the field is handled at least twice individually in the process of pulling and setting at which times they are subject to infection if the hands of the workers are contaminated. This may account for field infection and also for mosaic which frequently appeared in beds free from infection at pulling but which were found by Wolf to be infected following first pulling. Wolf concluded that his evidence "shows that the careless use of manufactured tobacco constitutes the most common source of inoculum for mosaic in the flue-cured areas."

Lehman (15) conducted well planned and executed field experiments during three years to determine the part which overwintering of the virus in the field played in subsequent field infection in North Carolina. He recognized the possibility of infection while weeding, pulling and setting by workers who used tobacco, and he tried to prevent it. All plants of certain plots were inoculated in August of one year, and the diseased plants either disked in the fall, allowed to stand over winter when they were disked, plowed under in fall or spring, or removed from the land in fall or spring. In 24 plots, or all in which tobacco followed tobacco which was infected 100 percent, and to some of which additional infected stalks were added, 5834 plants were grown. In these plots 108 plants or 1.8 percent, developed mosaic by about the middle of August or nearly harvest time. Diseased plants were removed when found and the plots cultivated only following removal. It seems evident that in North Carolina overwintering in roots or soil is a very minor factor, if spread from infected plants can be prevented, and one which, as both Wolf and Lehman have shown, can be largely overcome by fall removal, fall disking, or deep plowing in the spring, and roguing before cultivation (15, 24). Lehman's results give very little sup-

port to the theory of soil carry-over, but do give proof that if a sufficient amount of virus-carrying material is disked into the soil in the spring, some plants will become infected from this source by topping time. He concluded that "few, if any, of the more serious diseases of this crop may be more easily or more effectively controlled by means easily within the reach of every grower. The occurrence of a high percent of this disease in any field may usually be ascribed to lack of understanding of the nature of the disease and of certain simple ways by which it may be controlled or to carelessness in application of preventative measures." This conclusion seems to be entirely justified by facts now known about mosaic.

Anderson (3) reported in 1936 that in the Connecticut Valley where tobacco is grown year after year on the same land, there are "many indications that at least part of our bad infestation may start from the same source" (chewing and smoking tobacco used by workmen).

Soil Carry-over Studies in Kentucky. Estimates made independently by ten of the more experienced county agricultural agents in tobacco-growing counties in Kentucky, indicate that not over 10 percent of the crop is grown on land which was in tobacco the previous year. This largely eliminates soil carry-over as a possible source of initial infection in the State. In spite of this, mosaic may be an abundant and serious disease (tables 1, 3, 4, 7, 9).

In 1931 a study was begun to determine the extent to which soil carry-over might be a factor in mosaic infection in Kentucky where fields are used for tobacco two years or more in succession. A field was used in this study which had been cropped to tobacco continuously for more than 15 years. From one part of the plot mosaic plants, when found, were removed immediately. In the other part the plants were inoculated with mosaic when they approached the blooming stage. Except one year, strains of mosaic were used which could easily be recognized the following year. Inspection of the plots was made at intervals from about 18 days after setting until the tobacco was about three-fourths grown when the mosaic plots were again inoculated for carry-over studies the following year. Mosaic plants were removed as soon as found, to

Table 12. Soil carry-over studies of yellow mosaic, mosaic burn, and four strains of green non-burning mosaic. Figures show the number of plants infected with the same virus as was present the previous season. Figures and letters in parenthesis show the number of plants infected with some other virus, and its kind; b = mosaic burn, y = yellow, and g = green mosaic.

Year	Date set	Plot number	Total plants	Treatment previous year	Mosaic plants found and removed at each inspection						Infection attributable to soil
					First	Second	Third	Fourth	Fifth	Sixth	
1933	5-31	1	894	Mosaics removed	0	(7[1])	(11)	(4)	(6)	—	0
		2	436	Yellow mosaic	(1g)	(2g)[2]	(3g)[2]	(1g)[2]	0	—	0
		3	353	Green mosaic	0	0	(1y)	1	0	—	1
1934	5-29	1	857	Mosaics removed	0	(2g)	(3g)	0	—	—	0
		2	430	Yellow mosaic	0	0	1	0	—	—	1
		3	428	Severe green	0	(1y)	0	0	—	—	0
1935	6-1	1	1,024	Mosaics removed	0	(3g)	0	0	—	—	0
		2	510	Yellow mosaic	0	1(3g)	(1b)	0	—	—	1
		3	514	Mosaic burn	0	5[3]	3	5	—	—	8(5[3])
1936	5-25	1	835	Mosaics removed	(1y)	0	0	0	0	0	0
		2	412	Yellow mosaic	(2g)	(6g)[2]	0	0	(1g)	0	0
		3	406	Mosaic burn	0	0	1	(1g)	(2g)	(1g)	1
1937	6-7	1	420	Mosaics removed	0	(1b)	0	0	0	0	0
		2	449	Green mosaic	(1y)	0	0	2	0	0	2
		3	417	Yellow mosaic	(1g)	0	0	1	1	0	2
		4	465	Mosaic burn	0	0	0	0	0	0	0

1 Not removed until next inspection. 2 All of same type and all in group. 3 Type not recorded.

prevent spread. There is little evidence from four years' tests that infection from soil is other than a very minor factor (table 12). In 1935, of the 2.5 percent of the plants in the mosaic-burn plot which developed mosaic, 1.5 percent were mosaic burn which almost certainly came from virus carried over from the previous year's crop; the kind of mosaic in the other 1 percent was not recorded. This was the only year, however, when a possibly significant amount of mosaic occurred which could be attributed to soil carry-over.

While there is no doubt that the mosaic virus is present in the dead roots of tobacco plants in the spring of the year following a heavily infected crop (table 13), the probability that infection will be caused in a new crop set in the land needs consideration. Before a crop is set it is common practice to stir the ground with a disk as often as is convenient. After the crop is set the ground is cultivated at least once before the plants attain much size. Frequent stirring of the soil stimulates biological activity as evidenced by the high nitrate content of tobacco soils at setting time. High biologic activity tends to reduce virus concentration, and Lehman (16) and J. Johnson (14) have pointed out that drying the soil quickly inactivates the virus. The combination of a high biologic activity and drying of the surface layer of soil following frequent stirring during the spring and early summer should result in a relatively sterile surface layer as far as virus is concerned. It is not surprising, then, if infection does not commonly occur thru roots as seems to be agreed, that infection of plants in contaminated soil is rare.

A critical study of the published evidence on soil carry-over indicates that, except in fields in which the stubble lives thru the winter, and where tobacco trash is applied to a tobacco field in the spring, Allard's conclusion of 1914 is still valid. He stated "Although the opinion seems to be quite generally held that the refuse of mosaic plants plowed into soil may be responsible for the disease, there is little evidence to support this view" (1).

INFECTION FROM CONTAMINATED MATERIAL ADDED TO THE SOIL BEFORE SETTING

Infected stalks or stalks and leaves were saved from the overwintering experiment each year and added to plots on land which

had not grown a crop of tobacco for several years. Proper precautions were taken to see that only mosaic-free plants were set. The chopped or ground stalks and leaves were scattered on the plots before the last disking and were disked in lengthwise of the plots. If infection occurred, the type of mosaic must correspond with that of the virus added before it was considered proof of infection from the material added. Mosaic plants were removed at each inspection to prevent spread. Inspections were made at fairly regular intervals thruout the growing period. The results obtained were strikingly different from those where infected stubble alone was the source of contamination as infection was high each year (table 14). These tests show that if the virus is present in the upper soil layer, infections will occur up to topping time at least. Infection was higher when the stalks and leaves were ground in a hammer mill than when chopped into large pieces.

Attention should be called to the 1937 test in which the plants were set by hand with no precautions to prevent spread of infection at setting time from plots to which ground mosaic material had been added to those to which none had been added. Most of the infections in the untreated plots occurred early in the experiment and were evidently caused by contamination of the hands of the workers from contact with the ground material added to the soil of a treated plot.

Table 13. Infection of tobacco plants from virus overwintered in field soil. Soil from around tobacco plants that had been inoculated the previous summer with yellow or green mosaic was made into a thin paste and rubbed on the leaves of plants which were then set in flats of the same kind of soil.[1]

Date of collection of soil and transplanting	Plot from which soil was obtained	Number of plants set	Mosaic plants found	
			Yellow	Green
March 25	Contaminated	42	1	10
April 6	Contaminated	80	5	10
April 6	Uncontaminated	78	0	0
May 16	Contaminated	122	3	5
May 16	Contaminated[2]	56	0	0
May 16	Uncontaminated	50	0	0
May 30	Contaminated	113	2	3
June 11	Contaminated	38	0	4

1 A total of 36 healthy plants were rubbed with composite samples of bits of leaves from each plant before transplanting to be certain of their freedom from mosaic. These plants all remained healthy. 2 Plants not inoculated but set in contaminated soil.

Table 14. Incidence of tobacco mosaic in tobacco planted in ground in which viruliferous tobacco stalks and leaves containing mosaic burn (b), yellow mosaic (y), and green non-burn virus (g), had been mixed, immediately before setting, on different plots. Numbers alone show the number of mosaic plants found of the kind applied. Numbers and letters in parentheses show the number and kind of mosaic plants of other kinds found.

Rows	Number of plants set	Kind of virus in added material	Number and kind of mosaic plants found in each inspection								Percent of mosaic plants attributable to added material
			1st	2nd	3rd	4th	5th	6th	7th	8th	
	1933. Plants set May 23										
3-8	276	None	0	0	0	0	0	—	—	—	0.0
9-14	264	Yellow mosaic[1]	0	2(1g)	2	0	(1g)	—	—	—	1.5
15-20	245	Green mosaic[1]	0	4	5	6	1	—	—	—	6.5
	1934. Plants set June 3										
1-4	390	None	(1g)	(3g)	(1g)	(3g)	—	—	—	—	0.0
5-8	384	Yellow mosaic[1]	3	4(1g)	2	2(2g)	—	—	—	—	2.9
9-12	334	Green mosaic[1]	2	9	5	9	—	—	—	—	7.5
	1935. Plants set June 5										
1-4	358	Yellow mosaic[2]	38	20(1b1g)	14	9	4	4	—	—	24.9
5-8	369	None[3]	(3y)	(6y)	(3y)	(1b)	(1y)	(1y)	—	—	3.9
9-12	341	Mosaic burn stalks[2]	39(1y6g)	44(2y2g)	13	8(5y1g)	4(1y)	1(3y2g)	—	—	31.9
13-16	371	None[3]	(2b1g)	(1b)	(1b)	(1b1y1g)	(1b1y)	(1y1g)	—	—	1.7
17-20	362	Yellow and mosaic burn leaves[4]	71b13y(5g)	38b1y(7g)	14b6y(3g)	18b(2g)	8b	1b7y1g	—	—	41.4
21-24	363	None[3]	2b2y4g	12b7g	1b1y1g	3b1g	3b	1b	—	—	6.0
	1936. Plants set June 1										
1-4	329	Mosaic burn stalks	26	59	22	10	5	0	—	—	37.1
5-7	357	None	0	0	0	0	0	0	—	—	0.0
8-11	328	Mosaic burn leaves	6	10	6	3	2	1	—	—	8.5

1 Stalks chopped into pieces of an inch or more. 2 Stalks and leaves ground in a hammer mill, in 1935 and subsequently. 3 Wind was blowing when the finely ground material was being applied to the "infection" plots. 4 Mixed by accident.

Table 14. (Continued)

Rows	Number of plants set	Kind of virus in added material	Number and kind of mosaic plants found in each inspection								Percent of mosaic plants attributable to added material
			1st	2nd	3rd	4th	5th	6th	7th	8th	
12-14	248	None	0	(1b)	(1b)	(1b)	0	0	—	—	1.2
15-18	337	Yellow mosaic stalks	16	14	8	2	2	1	—	—	12.5
19-21	252	None	0	(3y)	0	0	(1y)	(1y)	—	—	2.0
22-25	331	Yellow mosaic leaves	13	18	6	2	4	0	—	—	13.0
26-28	252	None	(1y)	(1y)	0	0	0	0	—	—	0.8
1937. Plants set June 7[5]											
1-4	285	Mosaic burn stalks	89	16	15	10	9	0	7	3	52.3
5-7	238	None	(26b1y)	(6b)	(1b)	(4b)	0	(2b)	0	(2g)	16.8
8-11	294	Mosaic burn leaves	103(3y)	41	22	7	10	3	5	4	67.3
12-14	212	None	(3y1g)	(1b2g)	(2b1g)	(2b1y)	(1b)	0	0	(3g)	6.6
15-18	302	Yellow mosaic stalks	64	25	11	0	5	4(1g)	1(1g)	2(1g)	37.1
19-21	215	None	(4y)	(2y)	0	0	0	0	0	0	2.8
22-25	303	Yellow mosaic leaves	56	11	10	6	10	0	0	0	30.7
26-28	220	None	(2g)	(1b3g)	(1g)	—	0	0	0	0	3.2
29-32	231	Green mosaic stalks	25	4	16	7	0	1	2	2	24.7
33-35	210	None	(2g)	(5g)	(3g)	(1g)	0	0	0	0	5.2
36-39	245	Green mosaic leaves	53	39	25	7	6	1	1	6	56.3
40-42	223	None	0	(2g)	(1g)	(1g)	0	(1g)	0	0	2.2

5 The tobacco was set by hand, the crew of 4 men working from row 42 to row 1. This and a heavy rain before setting with wash toward the higher numbered rows probably accounts for most of the mosaic in the rows to which nothing was added as the mosaic material was added when the air was still. The plants grew very slowly after setting, and many mosaic plants which first showed symptoms as much as 6 weeks after setting were believed to have been infected at setting time.

SUMMARY

1. Tobacco mosaic can be controlled by practices designed to prevent initial infection in the plant bed and field. When complete success is not attained in the prevention of field infection, roguing the few mosaic plants which occur, before cultivation, prevents field spread.

2. The most common source of plant-bed and field infection appears to be the workers' hands which have become contaminated from handling viruliferous tobacco used for smoking or chewing. Air-cured and fire-cured tobaccos from infected crops are highly viruliferous.

3. In general the manufactured tobaccos appear to be free from virus or to have a very low virus concentration or for other reasons appear relatively safe for use when setting tobacco. Unless they are virus-free they are probably not safe to use while weeding.

4. Mosaic control appears to be beyond the experimental stage and is being put into successful practice by farmers in Kentucky and other southeastern tobacco-growing states.

5. Infected perennial solanaceous weeds growing on farms where tobacco has been grown frequently may constitute a reservoir of mosaic. This source cannot be disregarded in future studies on initial mosaic infection altho there is now only circumstantial evidence that occasional plants become infected from this source.

6. Insects such as aphids and possibly some other sucking and biting insects may play a part in initial mosaic infection in the field but infection from this source, if it occurs, is minor.

7. While much emphasis has been placed on contaminated soil as a source of initial infection, there is little evidence favoring it. In the south, where roots of plants live thru the winter and mosaic suckers are produced, they can undoubtedly cause infection of an occasional plant. Farther north where plants are killed during the winter there is evidence of very slight infection from virus overwintering in the soil. Where this source of infection has been adequately studied, roguing has been found to be a simple and successful means of preventing injury to the crop if all other sources of infection have been eliminated.

8. Where viruliferous tobacco trash is applied to the land short-

ly before setting, heavy infection may result even tho the infected plants are rogued as soon as mosaic develops.

9. Tobacco mosaic may be controlled satisfactorily under farm conditions by: 1, keeping all tobacco trash of the previous year's crop away from the plant bed and the field; 2, having the hands and pockets of the workers free from tobacco which carries the virus; that is, have them wear clean clothes, or brush all crumbs from their pockets, and wash their hands thoroly with soap and water before handling plants in the plant bed, while setting, and after the plants are in the field; 3, removing from the field all plants which develop mosaic during the summer, preferably before cultivating the crop, and not handling any other plants until the hands have been thoroly washed.

LITERATURE CITED

1. Allard, H. A. The mosaic disease of tobacco. U. S. D. A., B. P. I., 40;1-33. 1914.

2. ———— Further studies of the mosaic disease of tobacco. Jour. Agr. Research, 10: 615-631. 1917.

3. Anderson, P. J. Tobacco diseases in 1935. Bul. 386, Conn. Agr. Expt. Sta. Report of Tobacco Substation at Windsor for 1935: 594-595. 1936.

4. Annual Report Ky. Agr. Expt. Sta. for 1925: 12-13. 1926.

5. ————————————————1928: 14. 1929.

6. Busch, Hans J. and Frederick A. Wolf. Manufactured tobacco, a source of inoculum for mosaic in flue-cured tobacco. Phytopath., 23: 839-841, 1933.

7. Clinton, G. P. Chlorosis of plants with special reference to calico of tobacco. 38th Ann. Rep. of the Conn. Agr. Expt. Sta. Part 6, Rept. of the Botanist for 1914: 357-424.

8. Findings in farm science from Wisconsin's proving grounds. Wis. Agr. Expt. Sta., Ann. Rept. of Director for 1935-36. p. 104. 1937.

9. Fukushi, Teikichi. On the modes of transmission of the mosaic disease of tobacco. Jour. Sapporo Society of Agric. and Forestry, 22: 305-320. 1931.

10. Hoggan, I. A. Further studies on aphis transmission of plant viruses. Phytopathology, 21: 199-212. 1931.

11. Johnson, E. M. Virus diseases of tobacco in Kentucky. Ky. Agr. Expt. Sta. Res. Bul. 306: 289-415. 1930.

12. Johnson, James and W. B. Ogden. The overwintering of the tobacco mosaic virus. Wis. Agr. Expt. Sta. Res. Bul. 95: 1-25. 1929.

13. ———— Cucumber mosaic on tobacco in Wisconsin. Phytopath., 23: 311, 1933.

14. ———— Factors relating to the control of ordinary tobacco mosaic. Jour. Agr. Res., 54, 239-273. 1937.

15. Lehman, S. G. Contaminated soil and cultural practices as related to occurrence and spread of tobacco mosaic. North Carolina Agr. Expt. Sta., Tech. Bul. No. 46: 3-43. 1934.

16. ———— Inactivation of the virus of common tobacco mosaic by drying and by freezing in soil. Jour. Elisha Mitchell Scientific Soc., 52: 159. 1936.

17. Mayer, Adolf. Ueber die Mosaikkrankheit des Tabaks. Landw. Vers. Stat., 32: 450-467. 1886.

18. Report of a committee of the Tobacco Disease Council dealing with virus diseases of tobacco. The Ext. Patholog., U. S. D. A. Serial No. 27, April, 1937.

19. U. S. gives warning. Lexington Leader, Feb. 20, 1933.

20. Valleau, W. D. and E. M. Johnson. Observations and experiments on the control of true tobacco mosaic. Ky. Agr. Expt. Sta., Bul. 280: 145-174. 1927.

21. ———— and ———— Commercial tobaccos and cured leaf as a source of mosaic disease in tobacco. Phytopath., 17: 513-522. 1927.

22. ———— and ———— Some virus diseases of tobacco in Kentucky. Abs. in Phytopath., 18: 132-133. 1928.

23. ———— and ———— Tobacco diseases. in Kentucky. Ky. Agr. Expt. Sta. Buls. 328, 1932, and 362, 1936.

24. Wolf, Frederick A. Roguing as a means of control of tobacco mosaic. Phytopath., 23: 831-833, 1933.

25. ———— Tobacco diseases and decays, i-xix, 1-454. Duke University Press, Durham, N. C. 1935.